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ERGONOMIC EVALUATION OF DEVELOPED PEDAL OPERATED MILLET THRESHER FOR THRESHING OF FINGER MILLET

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ABSTRACT

Millet is one of the oldest human foods and is important food for sustaining tribal population in Bastar region of Chhattisgarh. They are using traditional methods like manual beating on wooden platform and rubbing ear heads of finger millets etc. The traditional methods of threshing are inefficient in operation, low output, higher grain damage and involved more drudgery to the farmers. The result of this analysis is also employed to improve the performance of pedal operated finger millet thresher.Finger millet threshing was evaluated on the basis of physiological and psychological ergonomics parameters viz. Heart Rate, Blood Pressure, Energy Expenditure Rate, Total Cardiac Cost of Work, Physiological Cost of Work for estimation of fatigue. The average working heart rate (HR work) of the subjects thresherranged between 116-129 beats/min. Energy expenditure rate (EER) was observed to be 14.00 to 17.8 kJ/min. The overall discomfort rating (ODR) of the respondents was found with a score of 3.2 ±0.30 by using pedal operated millet thresher.

KEYWORDS: *Finger Millet, Pedal Operated Millet Thresher, Traditional Method, Ergonomics*

Original Article

INTRODUCTION

Agricultural sector continues to be an important component of Indian National Economy with a contribution of about 22 percent to the GDP. India is the largest producer of many kinds of millets and most important minor millets cultivated in India are: finger millet (ragi), proso millet, barnyard millet, italian millet, kodo millet, little millet, job's tears and, teff. In India, finger millet occupies about 2.65 million hectares and it has total production of about 2.9 million tones.Chhattisgarh is a predominantly tribal and rice growing region. Its constituent agro climatic zones are Chhattisgarh plain, Bastar plateau, and Northan hills with 29 districts. Out of which 10 districts belong to Chhattisgarhplain. Millets are small-seeded grasses that are hardy and grow well in dry zones as rain-fed crops, under marginal conditions of soil fertility and moisture. Millets are also unique due to their short growing season. Finger millet is also known by the name Ragi. of the total area of 23 million ha under millets, small millets alone account for about 3.5 million ha. The person can generate four times more power (1/4 horsepower (hp)) by pedaling than by hand cranking. At the rate of 1/4 hp, continuous pedaling can be done for only short time, about 10 minutes. However pedaling at half of this power (1/8 hp)can be sustained for around 60 minutes Maximum power produced with legs is generally limited by adaptions within the oxygen transportation system.

On the other hand the capacity for arm exercise is dependent upon the amounts of muscle mass engaged and that is why a person can generate more power by pedaling than hand cranking (Tiwari P.S., 2011). Pedal power enables

a person to drive device at same rate as achieved by hand cranking but with less efforts and fatigue.

It is estimated that harvesting and threshing of crops consume about one third of the total effort requirement of the production system. (Sreenatha A., 2010).The traditional method for threshing of kodo millet and finger millet is generally done by hand. Bunches of panicles are beaten against hard elements (e.g. a wooden bar log, bamboo table or stone). In many areas, the crop is threshed by being trodden underfoot by humans or animals (Naveen et al., 2013). Studies on agricultural operations show an increasing involvement of women in crop production (Gite et al. 1997).Bullock treading and beating of paddy bundle on wooden or stone platform are the two methods farmers still practice in these states although it has low output, higher grain damage and involved more drudgery to the farmers. The heart rate and oxygen consumption rate required for paddy threshing by beating the crop on stones or wooden block were 135.8 beats/min and 0.920 l/min (Nag and Dutta, 1980) and 132 beats/min and 1.01 l/min (Karunanithi and Tajuddin, 2003). The energy consumption is 17-21.5 kJ/min that can be termed as a 'heavy' work as proposed by Nag and Nag (2004).

The present design of threshers available in the market are mostly for threshing of cereal and legume crops for rather than minor millets like finger millet (Ragi) and kodo millet, hence only conventional method is used by the farmers. Threshing process of the millet is a major constraint in this regard. Threshing of finger millet in pedal operated millet threshing requires both leg and hand coordination. During threshing, pedal operation is continuous, both leg on the pedal. In addition to that, the operator keeps on spreading the crop bundle on the threshing drum so that ear heads get detached. This requires suitable hand orientation to keep the crop spreading. Further, the operator needs to adjust the bodyweight for pedaling. The operator has to exert leg force on the pedal on its downward movement and has to lift the secondleg when the pedal moves upward so that the retardation of the pedal by the weight of the leg is less. However, small retardation cannot be avoided, as the pedal movement is very fast. Separation of grain from the ear head is faster at higher peripheral speed of the threshing drum that requires application of more force at the pedal. The body discomfort is induced not only by muscle movement but also by the effort to maintain static body posture while operating the thresher. This makes pedal threshing a complex work and its ergonomics need to be studied.

MATERIALS AND METHODS

To achieve enhanced performance and efficiency of man- machine system along with better comfort and safety of operators, it is necessary to design various tools, equipment and workplaces keeping in consideration the anthropometric data of agricultural workers. The ergonomicale valuation of pedal operated millet thresher was conducted with male and female agricultural operators of the farm of Faculty of Agricultural Engineering, Indira Gandhi Agricultural University, Raipur, Chhattisgarh, India, in a month of May 2014. One person was engaged for supplying the crop bundle to the operators. At the end of each experiment, the subjects were given 10 minutes rest so that all the physiological parameters regained to their resting level. The ambient temperature and relative humidity during experiments period were 20.6 ± 0.75 ^{0}C and 45 ± 6.8 % respectively. At the end of each experiment, the subjects were given 30 minutes rest so that all the physiological parameters regained to their resting level.

Finger Millet threshing was evaluated on the basis of physiological and psychological ergonomics parameters viz. Heart Rate, Blood Pressure, Energy Expenditure Rate, Total Cardiac Cost of Work, Physiological Cost of Work for estimation of fatigue. The detail specification of the thresher is given in Table 1.

Table 1: Specification of Pedal Operated Millet Thresher

S. No.	Particulars	Specifications
1.	Type of machine	Pedal operated millet thresher
2.	Suitability of crops	kodo and Finger millet
3.	Overall dimensions LxWxH(mm)	2500 x 1130 x 1140
4.	Power transmission unit and drive	Pedal operated, chain and belt drive
I.	Drive type	Chain and sprocket, V belt and pulleys
a.	Larger sprocket dia. (mm)	250 (60 teeth)
b.	Smaller sprocket dia. (mm)	70 (18 teeth)
II.	Pulley Size	
a.	Cylinder dia. (mm)	Step pulley with 50, 100 and 130
b.	Blower dia.(mm)	140
c.	Shaker dia. (mm)	225
III.	Belt sizes Cylinder- Blower Main pulley - cylinder Cylinder-shaker	 A- 42 A- 74 A-54
5.	Crop feeding device	
I.	Type	Chute type
II.	Method of feeding	Manual, Whole plants or Hold on method
III.	Height above ground, mm	1000
IV.	Size of opening, mm	300 x 200
6.	Threshing cylinder	
I.	Type	Spike Tooth
V.	Size of spikes, mm	10 X 60 & 25 x 55
VI.	No. of spikes	52 in 12 rows
7.	Concave	
I.	Type	Grate type
8.	Blower	Aspirator Type
9.	Sieve Shaker Assembly	Oscillating type
a.	Top sieve	3 mm hole, 450 x 350 mm
b.	Bottom sieve	2 mm hole, 550 x 350 mm

Selection of Subjects

A total of selected 10 farm workers of 5 male and 5 female in the age group of 20-45 years with random sampling technique were taken for data collection (Mc Ardle et al. 2001). The activities were carried out with 3 replications and time bound for 30 min without rest break for analysis of various research parameters. The present study of anthropometric dimensions of agricultural workers for pedal operated millet thresher, anthropometric data of 10 dimensions has been completed for 05 male agricultural workers and 05 female agricultural workers. All the subjects were right handed, physically fit and were not suffering from any physical anamalities to perform the selected activity.The details of the physical measurements of these subjects are placed in table 2 and table 3.

Figure 1: Operational View of Pedal Operated Millet Thresher

Data Analysis

From the data collected during the survey, the arithmetic mean, standard deviation, range, 5th and 95th percentile values were computed for each of the body dimensions. This was repeated not only to each of the district but also to the total sample. Mean value was computed by adding the individual values and dividing the sum by the sample size. It indicates where the distribution is located on the horizontal axis.

The Standard Deviation was Computed by using the

$$SD = \sqrt{\{(X-M)^2/(N-1)\}}$$

Where, SD= Standard deviation of the dimension.

M = Mean value of the Dimension.

X = Individual value of dimension.

N = Sample size.

The standard deviation is an index of degree of variability in the population concerned. It indicates the width of distribution of the extent to which individual values are scattered about the mean.

The 5th and 95th percentile values were computed as

$$X_i = M + S\,Z$$

Where, X_i = ith percentile value of the dimension.

M = Mean value of the dimension.

S = Standard deviation of the dimension.

Z = Z-constant for the ith percentile.

For 5^{th} percentile Z = -1.645, and for

95^{th} percentile Z = + 1.645

The range of the dimension measured was taken by noting the minimum and maximum values among the subjects.

Measurement of Heart Rate

The subjects were allowed to take sufficient rest before starting the activity to determine the resting heart rate

(HR_{rest}). The HR work was measured between 6th to 20th minute of work of each subject as it is considered that the heart rate gets stable after 3-5th minute of the work (Astrand and Rodahl, 1977). The average HR was taken as representative value for each subject for the working duration. The HR was measured by stethoscope. Twenty observations were taken between 6-20th minutes and the average was taken as the representative HR.

$$\Delta HRKG = [\Delta HR / C].60$$

Where,

ΔHRKG = Increase HR/kg of grain threshed, beats/kg

ΔHR = (Mean working HR – Resting HR), beats/min

C = Capacity of the thresher, kg/h

Measurement of Pedal Force

The effort required for pedaling operation was measured using a hanging type weighing balance. The weighing balance was mounted in the foot pedal of the thresher and the worker applied the foot force. Twenty observations were taken during the threshing operation and the average was considered as the representative pedal force for an experiment (Fig. 4.7).

Measurement of Physiological Cost of Work

Circulatory stress was evaluated from the cardiac cost of work and cardiac cost of recovery. The cardiac cost of recovery is the total number of heart beats above the resting level occurring between the end of work and return to the resting state (Saha 1976). Heart rate was measured with polar heart rate monitor and recorded as HR=beat/ min

Following formula was used to calculate the total cardiac cost of work (TCCW) and physiological cost of work (PCW) (Singh et al. 2007).

Total cardiac cost of work = cardiac cost of work + cardiac cost of recovery.

TCCW = CCW + CCR; where

CCW = AHR × Duration of activity; where AHR = Avg. working HR- Average resting HR CCR = (Avg. recovery HR- Average resting HR) × Duration.

$$\text{Physiological cost of work} = \frac{TCCW}{Duration\, of\ work}$$

Energy Expenditure was calculated using the formula: EE (Kj/min) = 0.159 × HR (beats/min) –8.72

Overall Discomfort Rating (ODR)

Body posture is one of the major factor which causes muscular fatigue and discomfort in the body. Uncomfortable body posture in different activities reduces work efficiency, capacity and safety of operator. The effect due to working posture can be measured in terms of overall discomfort rate and body part discomfort rate techniques.

RESULTS AND DISCUSSIONS

Anthropometric Data of Agricultural Workers

Some important anthropometric body dimensions and calculated values of the parameters such as ponderal index, body mass index and lean body mass of male and female agricultural workers are given in Table 1 and 2 respectively. It can be observed that there exists a remarkable difference in anthropometric body dimensions of male and female agricultural workers.

Table 2: Analysis of Anthropometric Data of Male Agricultural Workers

S.N.	Dimension	Min. (cm)	Max. (cm)	Mean (cm)	Std. Dev.(cm)	5^{th} (cm)	95^{th} (cm)
1	Age years	29.0	46.0	36.3	7.05	24.7	47.9
2	Weight, kg	46.0	63.0	54.7	8.07	41.4	68.0
3	Stature	166.0	171.0	168.0	2.35	164.1	171.8
4	Vertical grip reach	194.0	214.0	202.4	9.63	186.6	218.3
5	Knee height	49.0	53.0	50.8	1.82	47.8	53.8
6	Sitting height	87.0	92.0	88.8	2.17	85.2	92.3
7	Sitting acromion height	59.5	69.5	62.9	3.86	56.6	69.3
8	Functional leg length	95.5	102.0	98.3	2.73	93.8	102.8
9	Thumb tip reach	73.0	80.0	75.4	2.70	70.9	79.8
10	Grip diameter, Inside	5.2	5.8	5.4	0.26	5.0	5.9
11	Foot length	23.0	25.5	24.6	1.08	22.8	26.4

Table 3: Analysis of Anthropometric Data of Female Agricultural Workers

S. N.	Dimension	Min. (cm)	Max. (cm)	Mean (cm)	Std. Dev.(cm)	5^{th} (cm)	95^{th} (cm)
1	Age years	25.0	43.0	34.7	7.64	22.1	47.3
2	Weight, kg	48.0	60.0	55.0	5.22	46.4	63.6
3	Stature	156.0	164.0	160.2	3.27	154.8	165.6
4	Vertical grip reach	192.0	209.0	199.3	6.15	189.2	209.4
5	Knee height	45.0	48.0	46.4	1.08	44.6	48.2
6	Sitting height	79.0	84.0	81.2	2.17	77.6	84.7
7	Sitting acromion height	52.0	59.0	56.0	2.97	51.2	60.9
8	Functional leg length	91.0	94.0	92.5	1.12	90.7	94.3
9	Thumb tip reach	73.0	76.0	74.2	1.15	72.3	76.1
10	Grip diameter, Inside	5.0	5.4	5.3	0.17	5.0	5.5
11	Foot length	22.0	24.0	22.9	0.82	21.5	24.2

Physical and Physiological Characteristics of the Subject

The mean resting heart rate of the subject was found to be 78.4 beats/min with a range of 70-80 beats/min. The peak heart rate values were recorded between116to 129 beats/min with mean value of 120.5 beats/min. The average energy expenditure was found 10.80 kJ/min. The peak energy expenditure values were recorded between 14.00 to 17.8 kJ/min with the mean value of 15.82 kJ/min.

Table 4: Physical and Physiological Characteristics of the Subjects

Physical and Physiological Characteristics	Range	Mean
Age, years	25-46	35.5
Weight, kg	47-63	54.9
Height, cm	156-171	164

HR_{rest}, beats/min	76-85	78.4
HR_{max}, beats/min	116-129	126.5

Heart Rate

The average working heart rate (HR work) of the subjects when the millet threshing with the use of pedal operated millet thresherranged between 116-129 beats/min. with a mean value of 120.5 beats/min. The peak heart rate values were found 129 beats/min by using pedal operated millet thresher. The heart rate recovered to its pre-work stage after 10 minutes after 20 minutes of work with pedal operated millet thresher.

Yadav and Pund (2007) reported a rest pause of 14 minutes while working with a manual weeder to restart the work where the peak heart rate of the subjects ranged between 142 to150 beats/ min. The increase the heart rate per kg of grain threshed was compared to assess the extent ofdrudgery, as heart rate is a major parameter in quantification of drudgery (Astrand and Rodahl 1977). Dewangan (2007) reported that the heart rate values per kg. of grain threshed was foundin the range of 123 - 179 beats/kg. with manual beating of paddy with the mean value of 154.4 beats/kg.

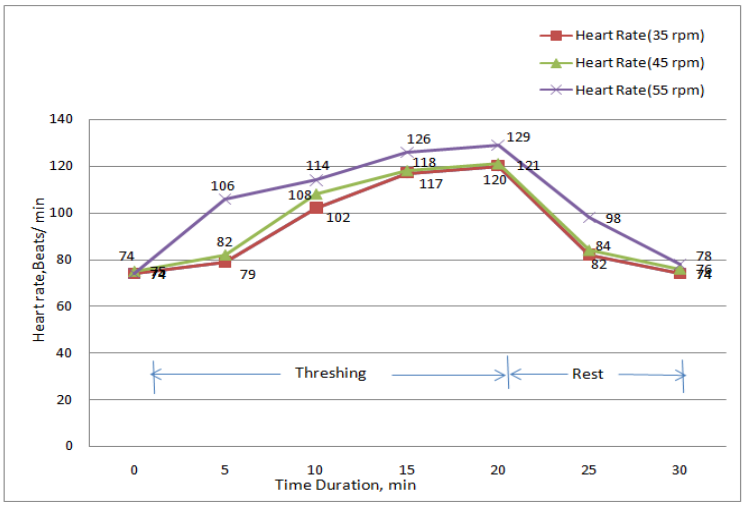

Figure 2: Mean Heart Rate and Recovery Pattern at Different Duration of Threshing Operation

Energy Expenditure Rate

Peak values of energy expenditure rate (EER) with use pedal operated millet thresher for threshing of finger millet was observed to be 14.00 to 17.8 kJ/min kJ/min. Based on the energy expenditure values the categorization of the agricultural work was done as per classification by Nag et al. (1980) given in table 4.

Table 5: Categorization of the Agricultural Work (Nag et al. 1980)

Variable	Light	Moderate	Heavy	Extremely heavy
Energy cost Kj/min	<9.10	9.10-18.15	18.15-27.22	>27.23

An extensive study on Indian Agricultural Operators to assess the occupational workload on the basis of individual capacity to perform work was conducted. Accordingly, threshing of finger millet by using pedal operate millet thresher can be categorized into the 'moderate' work.

Overall Discomfort Rating (ODR)

Table 2 gives the pain intensity score as measure of overall discomfort rate. The same score can be used for

measurement of body parts discomfort rating.

Table 6: Pain Intensity Score as a Measure of Overall Discomfort Rating (ODR)

Subjective Feeling	ODR Score	Subjective Feeling	ODR Score
Comfortable	0	Moderately painful	4
Uncomfortable	1	Highly painful	5-6
Pain starts	2	Very highly painful	7-9
Slightly painful	3	Extremely painful	10

The overall discomfort rating (ODR) of the respondents was found with a score of 3.2 ± 0.30 by using pedal operated millet thresher. The body parts with maximum discomfort were lower back, right upper leg, right lower leg, right foot, right upper arm, right forearm in the descending order as expressed by the subjects. The body parts discomfort was maximum in lower leg due to pedaling and feeding the crop in bent posture.

CONCLUSIONS

The ergonomic evaluation of millet threshing activity revealed that the physiological responses and physiological cost of work reduced significantly by using pedal operated millet thresher.Finger millet threshing was evaluated on the basis of physiological and psychological ergonomics parameters viz. Heart Rate, Blood Pressure, Energy Expenditure Rate, Total Cardiac Cost of Work, Physiological Cost of Work for estimation of fatigue.The average working heart rate (HR work) of the subjectsthresherranged between 116-129 beats/min.Energy expenditure rate (EER) was observed to be 14.00 to 17.8 kJ/min.The overall discomfort rating (ODR) of the respondents was found with a score of 3.2 ± 0.30 by using pedal operated millet thresher.

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